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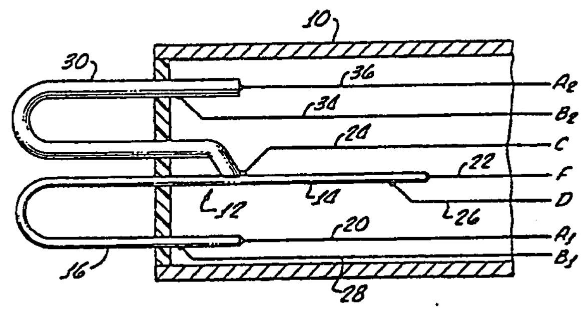
(58) Field of search
G1N

(54) A corrosion probe

(57) An electrical resistance corrosion probe having a test element 16 for exposure to the corrosive environment and a reference element 14 protected from corrosion inside a body 10, also includes a second test element 30 or alternatively a second reference element (114a, 114b), Figure 6 (not shown). The second test element 30 has a considerably greater diameter or is more resistant to corrosion than the first test element 16. The probe is used in a normal manner for the useful life of the primary test element 16 by monitoring the ratio of the resistance of the first test element 16 to that of the reference element 14. Thereafter, the instrumentation is switched to monitor the ratio of the resistance of the second test element 30 and the same reference element 14. In the alternative arrangement the resistance of the corroded first test element is compared with the second reference element having a higher resistance than the first reference element. The useful life of a corrosion probe is thus extended.

FIG. 1.



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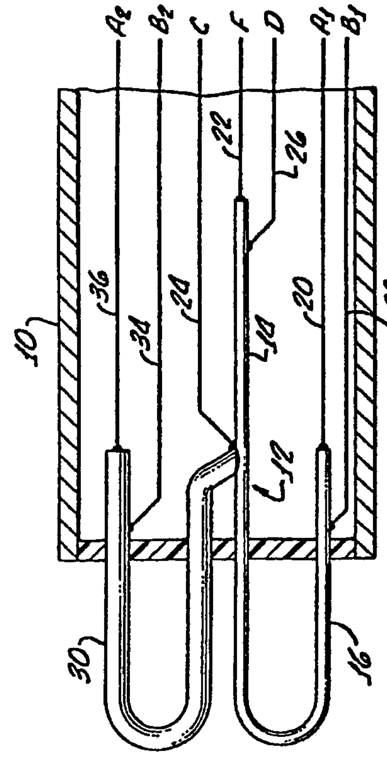


FIG. 1.

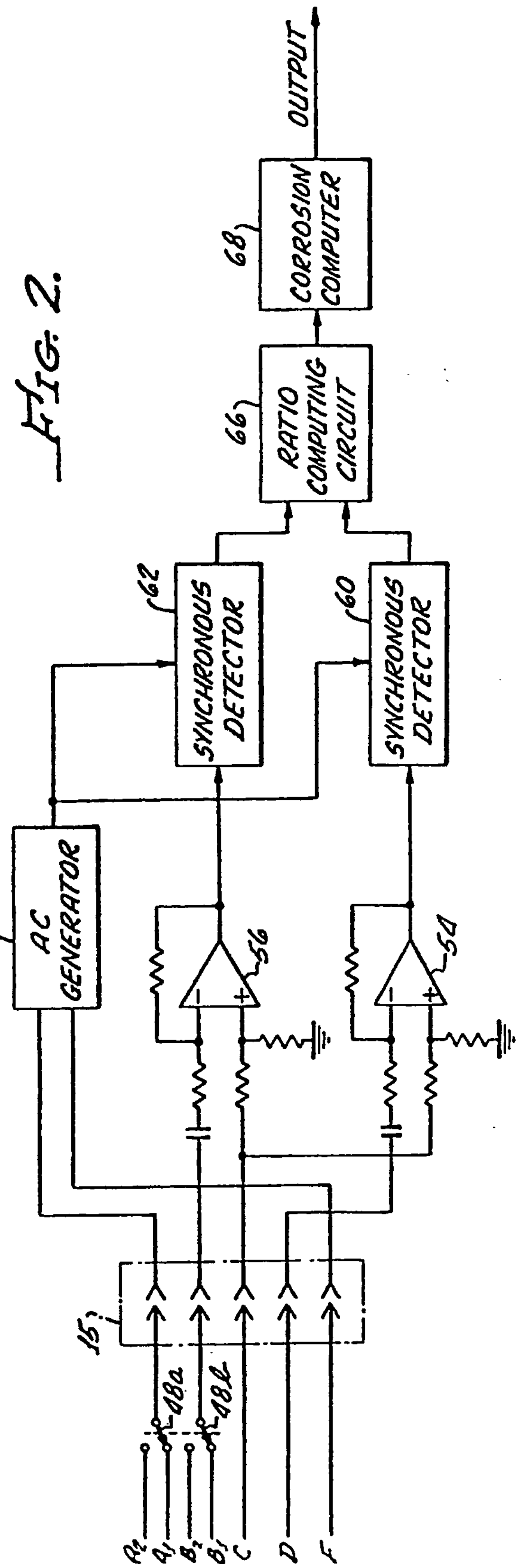


FIG. 2.

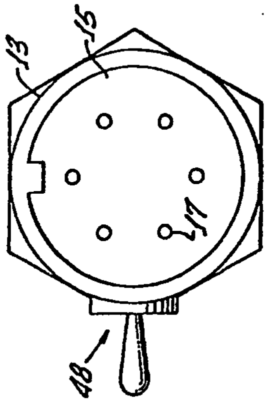


FIG. 5.

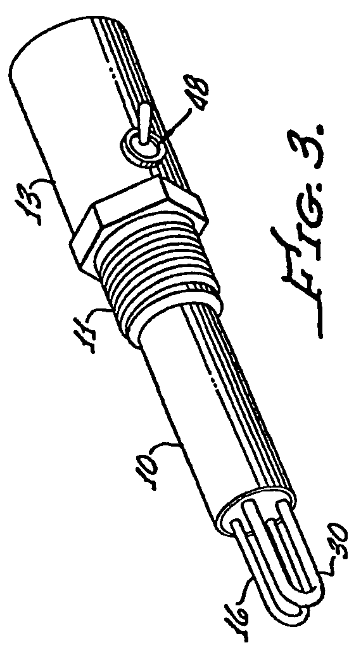


FIG. 3.

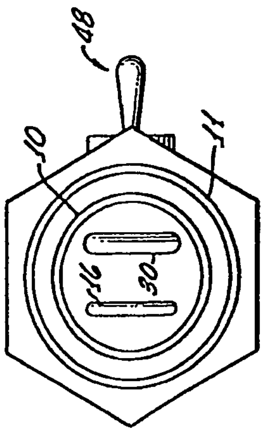
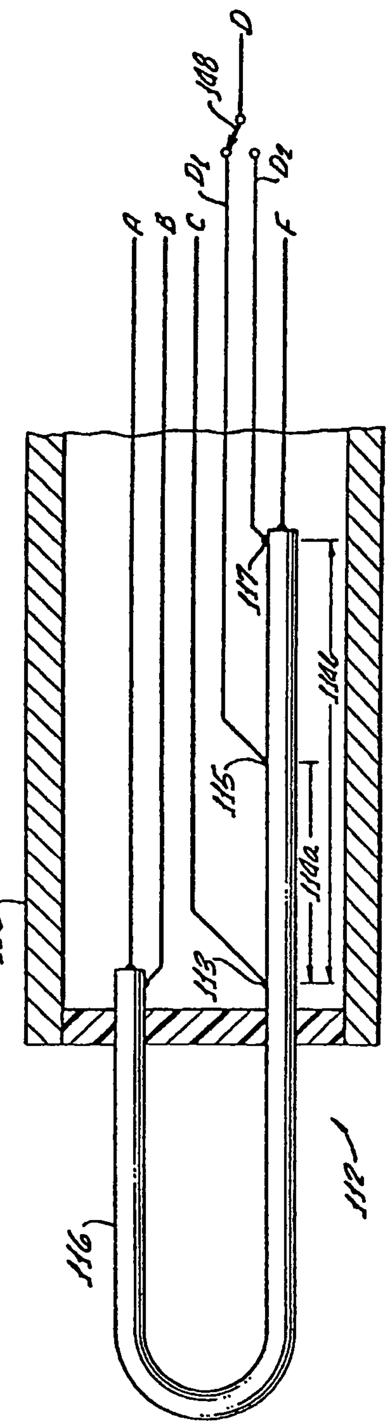


FIG. 4.

FIG. 6.



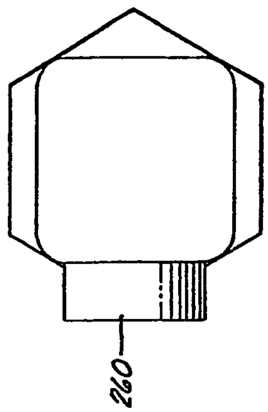


FIG. 10.

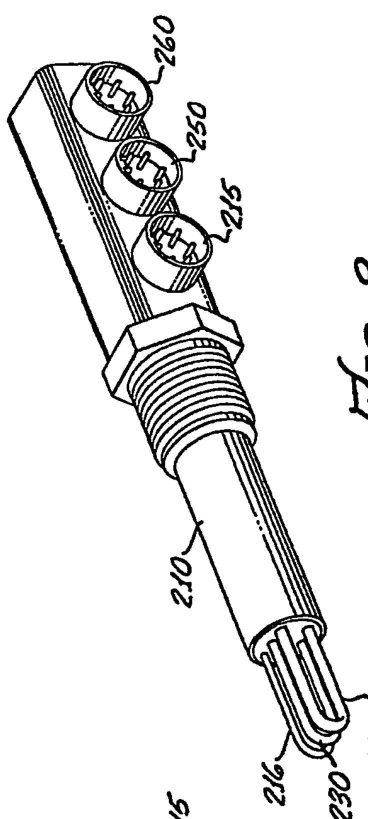


FIG. 8.

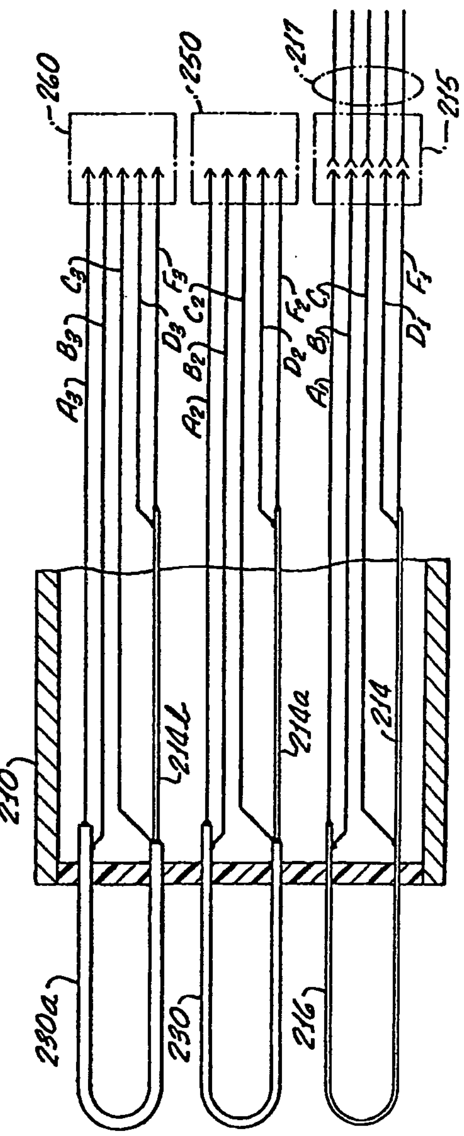


FIG. 7.

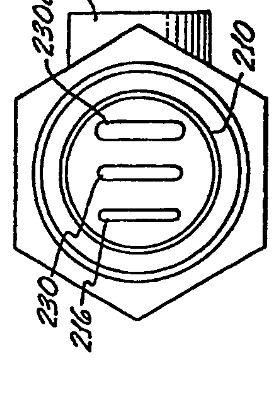


FIG. 9.

SPECIFICATION

A corrosion probe

Corrosion or erosion by fluids, such as oil and gas, transported or processed in pipelines or refining or other processing systems is measured by several different sensitive systems, including test coupons, polarization instruments and sensors, and electrical resistance probe instruments and sensors. The term corrosion, as used throughout this application, shall be construed to mean either corrosion or erosion, or both, including metal loss by chemical, mechanical or similar processes. Electrical resistance probes, which are one of the most commonly used corrosion monitoring sensors, generally use a probe body which is inserted into an environment the corrosive properties of which are to be monitored. A test element, which may be a wire loop or a metal cylinder, or the like, extends from the body for exposure to the corrosive environment, while a reference element within the body of the probe is protected from this environment. The reference element is used to provide temperature compensation and to enable measurement by means of a ratio of the resistance of test and reference elements in a bridge-type circuit. The latter enables measurement of smaller signals at longer distances than would be possible with an absolute measurement of resistance. Resistance of the test element changes with both its cross sectional area (which is decreased by the corrosion to be measured) and with temperature, while resistance of the reference element changes only with temperature. Therefore, a comparison of the resistance of the noncorroding reference element with the resistance of the test element is substantially free of temperature induced variation and indicates only corrosion effects. The measuring instruments employ various types of electrical and electromechanical compensation arrangements to provide a corrosion readout that accounts for non-linearities of the measured quantities.

Because of the nature of the measurement, namely, the actual loss of material from the test element, this element inherently has a finite life. Continued corrosion reduces the size of the test element to a point at which it no longer provides a useful resistance measurement. Further, as the element corrodes to a very small thickness, surface roughness may increase to a point where roughness is a large percentage of total thickness, so that the variation of electrical resistance with wire size is highly non-linear. This introduces significant and unacceptable uncertainties in the resistance measurement. However, a more significant limitation in many systems that have been previously installed and are presently operating is the fact that the compensation circuit is specifically designed for a useful probe life that results in an end thickness of the test element of about 50% of its initial thickness. Using more sophisticated digital processing instrumentation that is now available, it is possible to obtain useful readings with a test element that has corroded down to significantly less than 50% of its original size. Nevertheless, there are large numbers of instruments presently in use that do not operate after the test element has corroded to 50% of its initial size. Such instruments are set to provide a zero reading for the ratio of resistance of the new test element to the resistance of the reference element and to provide a full scale reading of this ratio when the test element has corroded to 50% of its initial thickness. Therefore, for these instruments that are presently installed and in use, the probe must be replaced when it is corroded to the point where the test element has 50% of its initial thickness. The time required for this amount of corrosion has been denoted as the useful life of the probe. Of course, such life varies according to the rate of corrosion, which, in turn, depends upon the actual corrosion characteristics of the fluid monitored.

It is generally desired to have as long a useful probe life as possible, a commonly desired life being one year or more. However, as useful probe life is increased for a given environment, probe sensitivity decreases. The greater the initial thickness of the test element, the less its sensitivity. This is due to the fact that for a given corrosivity of the environment, the percentage change in test element cross sectional area (and therefore in resistance) for a given period of time is less for a larger cross sectional area than it is for a smaller cross sectional area. Therefore, for increased sensitivity, initial test element size is desirably small. However, an initially small sized probe test element reaches the end of its useful life in a significantly shorter period than an initially thicker test element having a greater cross sectional area. For example, in a fluid having a corrosion rate of 20 mils (0.5 mm) a year for a particular probe test element material, a wire loop test element having an initial diameter of 40 mils (1.0 mm) when new has a diameter of 20 mils (0.5 mm) after six months (corrosion occurs around the entire periphery of the wire and wire radius decreases by 10 mils (0.25 mm). This is the end of the useful life of this probe when used with many existing measuring instruments. In such an environment, a wire test element having an initial diameter of 60 mils (1.5 mm) has a diameter of 40 mils (1.0 mm) at the end of the same period, and thus is far from the end of its useful life, but it is significantly less sensitive to changes in corrosion rate than the probe element of initially 40 mils diameter. Thus, the user desiring both long probe life and high sensitivity must sacrifice one to maximize the other.

When a probe reaches the end of its useful life, it must be replaced, and this requires operator time, the expense of the operator and the expense of a replacement probe. Furthermore, in some types of systems, operation of a plant or process must be completely shut down during probe replacement. This may be so because a pressurized system, for example, has the probe installed through a wall of the system so that pressure within the system must be released to remove and replace the probe. Thus, a longer probe life is highly desirable.

In some situations, the need for a probe of long life and the economics of frequent probe replacement dictate the use of a probe of longer life but of less sensitivity so that significant useful information that

would otherwise be available from a probe of higher sensitivity is lost.

According to this invention an electrical resistance corrosion probe comprises a probe body, test means mounted on and extending away from the body and being arranged to be exposed to a corrosive environment, reference means mounted on the body and protected from the corrosive environment to which the test means are exposed, the test or reference means comprising first and second resistive elements, and the other of the test or reference means comprising a third resistive element, means for generating first, second and third resistance signals respectively indicating the resistance of the first, second and third resistive elements, and measuring means for comparing the third resistance signal with the first resistance signal during a first part of the life of the probe and for comparing the third resistance signal with the second resistance signal during a subsequent part of the life of the probe.

Various examples of corrosion probes in accordance with this invention will now be described with reference to the accompanying drawings; in which:

Figure 1 is a partly sectional side elevation of part of a first example;

Figure 2 is a circuit diagram measuring circuitry for use with the probe;

Figure 3 is a perspective view of the first example;

Figures 4 and *5* are front and rear elevations respectively, of the first example;

Figure 6 is a partly sectional side elevation of part of a second example;

Figure 7 is a partly sectional side elevation of a third example;

Figure 8 is a perspective view of the third example;

Figures 9 and *10* are front and rear elevations, respectively, of the third example.

Illustrated in Figure 1 are portions of a typical corrosion sensing probe which may be of the type known as Corrosometer (Registered Trademark) Electrical Resistance Corrosion Sensing Probe, sold by Rohrback Instruments, of Santa Fe Springs, California, a Division of Rohrback Corporation. The probe illustrated uses a wire loop as its sensor or test element. It will be understood that principles of the invention also are applicable to electrical resistance corrosion probes employing different types of test elements, including cylindrical test elements, flat or loop strips, and all other commonly used shapes and styles.

A typical probe, includes a probe body 10 that is adapted to be inserted into a body fluid, such as oil or gas, so that exposure to the fluid will corrode the exposed test elements. The probe body includes a threaded and sealing portion 11 (Figure 3) of well known construction by means of which the probe is secured to and sealed within a threaded aperture through the wall of a container or pipe (not shown).

The generally cylindrical body 10 carries a pair of resistance elements made of a single continuous length of wire 12 having a reference element portion 14 and a test loop portion 16 integral with the reference portion 14. The two elements, the test and reference elements, need not be made from the same length of wire, but temperature characteristics are more readily matched to provide improved temperature when the test and reference elements are made from immediately adjoining sections of a single length of wire. In conventional fashion, leads 20 and 22 are connected to opposite ends of the integral combined test and reference elements to provide terminals A_1 and F by which an AC energizing current is applied to the elements. Leads 24 and 26 are connected to the reference element at a point close to the test element and at a point remote from the test element, respectively, to provide signals at terminals C and D indicative of resistance of the reference element 14. A lead 28 is connected to the other end of the test element 16 (the end remote from the reference element) to provide at terminals B_1 and C a signal indicative of the resistance of the test element. The reference element, of course, is protected from the environment, being sealed within the probe body or Teflon coated, and is not subject to corrosion. The probe body (Figure 3) has a connector section 13 mounting a receptacle 15 having pins 17 for reception of a connecting socket (not shown) that is coupled to the readout instrumentation.

The arrangement described to this point is conventional and typical of many known probes.

According to a preferred embodiment of the invention, a second test element 30 is provided, also mounted to the probe body, as is the test element 16. Ends of the second test element, which is made of the same material as are the reference and first test elements, also extend into the probe body, and one end is connected, such as by welding, to the reference element 14 and test element 16 at the junction between the two, thereby also being electrically connected to lead 24. Two additional electrical leads 34, 36 are connected to the other end of the second test element 30 so as to provide between terminals B_2 and C a signal indicative of the resistance of the second test element and to enable an AC energizing current to be transmitted to the combination of reference element and second test element through terminals F and A_2.

The second test element 30 is made of a wire having a larger cross sectional area (and, therefore, a smaller electrical resistance) than the wire of which the first test element 16 is made. The arrangement is such that the two test elements are concurrently exposed to the same corrosive environment when the probe is in use, and the relative areas of the test elements are so proportioned that when the first test element 16 has corroded to the end of its useful life, the second test element 30 will have corroded sufficiently to have a cross sectional area that is equal to, or substantially equal to, that of the first test element 16 when the latter was new. For example, assuming that test element 16 has an initial diameter of 40 mils, test element 30 will have an initial diameter of 60 mils so that when the first test element 16 has corroded down to a diameter of 20 mils (which is commonly considered to be the end of its useful life), the second test element 30 will have corroded enough to have a diameter of 40 mils (which is the diameter of the first test element when

new). At this time the electrical resistance of the second test element has increased to the value of the resistance of the first test element when new.

As previously mentioned, recently introduced digital instrumentation, which can continue to provide accurate information even after a test element has corroded beyond 50%, was preceded by electromechanical instrumentation that is generally capable of handling corrosion up to about 50%, but not capable of providing useful information beyond such 50% corrosion. Accordingly, probe useful life has been based upon the widely used, more limited electromechanical instrumentation. Probes constructed according to the present invention are particularly adapted for use with the prior more limited instrumentation, but may also be used with the more capable and sophisticated digital instrumentation.

In the measurement of corrosion by instruments of this type, corrosion rates and magnitudes are measured as ratios of the resistance of the test element to the resistance of the reference element. The use of the reference element allows temperature compensation, because resistance of the test and reference elements also vary with temperature and, in addition, permit the desired ratio measurement.

In use of the probe of Figure 1, the first test element 16 and reference element 14 are used in a conventional manner to generate temperature compensated corrosion signals based upon the ratio of resistance of the test element 16 to resistance of the reference element until the end of the useful life of test element 16. At this time, the test element will have, as indicated above, a diameter of 50% of its original diameter. At the end of the useful life of test element 16, the second test element 30, which initially has a diameter of one and a half times the diameter of the first test element, now has a diameter equal to the diameter of the first test element when the latter was new. Accordingly, the second test element may be substituted electrically for the first test element, and the resulting combination of test and reference elements is equivalent to the combination of the new test element 16 and reference element 14. In other words, merely by switching terminals A_1 to A_2 and B_1 to B_2 at the end of the useful life of the test element 16, the probe begins to use a second test element that is equivalent to the original test element. In effect, the probe's useful life has been doubled.

It has been found that in the large majority of common applications of a probe of this type, corrosion of a wire loop test element from 60 to 40 mils is substantially uniform and results in a 40 mil wire loop with an external configuration of a roundness and smoothness that is sufficient to provide accurate measurement.

Illustrated in Figure 2 is an exemplary and simplified circuit diagram of an instrument used for making corrosion measurements with the probe of Figure 1. The several leads from the probe body are brought out to individual pins of the probe receptacle 15. Leads A_1 and A_2 are connected to the same receptacle pin by means of a switch 48a, and leads B_1 and B_2 are connected to the receptacle by a switch 48b which is ganged with switch 48a. The switches, collectively shown at 48 in Figure 3, are mounted in the probe section that remains outside of the pipe or container in which is confined the environment being monitored. Accordingly, the switch actuator is accessible from outside of the pipe or container without removing or otherwise manipulating the probe and without breaking the sealing relation between the probe and pipe or container. Terminals A(A_1 or A_2) and F are connected to a source 50 of AC current, with terminal F connected directly to one side of the source and terminal A_1 connected to the other side of the source through the first switch 48a. A signal representing resistance of the reference element is fed via terminals C and D to the noninverting and inverting inputs of a first differential amplifier 54. The signal from terminal C is also fed to the noninverting input of a second amplifier 56 which receives at its inverting input the signal from terminal B via the second switch 48b. The ganged switches transmit signals from terminal B via the second switch 48b. The ganged switches transmit signals from terminals A_1 and B_1 when the first test element 16 is employed and from terminals A_2 and B_2 when the second test element 30 is employed. Signals from the amplifiers 54 and 56 are fed to first and second synchronous detectors 60 and 62 which are phase referenced from the AC signal source 50. The signals from the detectors 60 and 62 are fed to a ratio circuit 66 that provides a signal representing the ratio of resistance of the test element to the resistance of the reference element. This is the corrosion signal that is fed to a computing circuit 68 which provides an output signal for display and/or recording.

A typical output display will provide a readout scale that goes from 0 to 1000 units. The reading of this scale is monitored so that when the readout approaches full scale value of 1000 (which is the expected end of the useful life of the test element 16), the ganged switches are operated to switch the second test element 30 into the circuit, energizing the second test element instead of the first test element and reading resistance of the second test element instead of the first test element for comparison with the same reference resistance.

The usual time-consuming, expensive and inconvenient replacement of the entire probe at the end of useful life of the one test element is avoided. One need only monitor the corrosion output and operate the externally accessible switches to start a new life period for the second test element, so that probe life can be extended for the full life of the second test element merely by switching connections of two of the wires.

It will be readily appreciated that many modifications of the principles and concepts illustrated in Figure 1 are possible. Thus, instead of having only one additional test element, two, three or more additional test elements may be provided, each with appropriately increased diameters (that is, each having a diameter appropriately larger than the next). The number of such additional test elements is limited primarily by physical size and the ability to package the additional elements in a probe of

desired size, or by occurrence of unacceptably rough surface characteristics of a test element that has been exposed to the corrosive atmosphere for an excessive period. Three or more such test elements may be employed where it is found that the resulting surface roughness that occurs over the extended life still allows acceptable measurement accuracy.

Illustrated in Figure 6 is an alternate embodiment in which but a single test wire loop is employed with a pair of reference elements. In this case, the probe body 110 has a single wire element 112 formed with a pair of reference elements 114a, 114b and a test element 116. The test element 116 extends outwardly of the probe body for exposure to the corrosive environment and is integral with the reference elements. The latter are provided as two separately measurable lengths of the same wire length. Thus, a first reference element 114a is formed by the length of wire between points 113 and 115 to which terminals C and D_1 are connected. The second reference element, which has a significantly greater resistance than the resistance of the first, is formed by a greater length of the reference element between points 113 and 117 and is measured across terminals C and D_2. Terminals D_1 and D_2 are switched by a single switch 148. In this case the lengths of the wires are chosen so that when the ratio of resistance of the test element to the resistance of the first reference element 114a is at its end value (the test element having corroded to 50% of its initial area), the ratio of resistance of this corroded test element to the resistance of the second reference element, between points 113 and 117, is the same as the ratio of the new test element 116 to the first test element 114a. Obviously, a third or fourth section of the reference element wire may be provided to provide third and fourth reference elements of successively greater length and successively greater resistance. If four such reference elements have resistances identified as R_{R1}, R_{R2}, R_{R3} and R_{R4}, and the test element resistance is R_M, the lengths and resistances are chosen so that when R_M/R_{R2} is at some predetermined end value, R_M/R_{R2} will be the same as R_M/R_{R1} when the test element was new. Similarly, when R_M/R_{R2} is at some predetermined end value R_M/R_{R3} will be the same as R_M/R_{R1} when the test element was new. Again, when R_M/R_{R3} is at an end value, R_M/R_{R4} is at the new value or R_M/R_1. The arrangement of Figure 6 requires the switching of only one wire and, moreover, will provide improved temperature compensation, since the reference elements and test elements are all made from the same length of wire, whereas, in the embodiment of Figure 1, the second test element, having a greater diameter than the first test element, must be made from a different piece of wire (although of the same material) than the reference element.

Still another embodiment of the invention is illustrated in Figures 7 to 10 wherein three complete assemblies of test and reference elements are mounted in a single probe body 210. Thus, a first wire loop test element 216 integral with a first reference element 214 is provided and coupled to terminals A_1, B_1, C_1, D_1 and F_1, as previously described. A second complete assembly of a second wire loop test element 230 and a second reference element 214a are provided with the second test element having, in this exemplary arrangement, a diameter of approximately one and a half times the diameter of the first test element 216, and the second reference element 214a having the same diameter as the first reference element 214. Accordingly, when the first test element 216 has corroded to the end of its useful life, the second test element 230 has a resistance such that the ratio of such resistance to the resistance of the second reference element 214a is the same as the ratio of resistances of elements 216 and 214 when new. Leads A_2, B_2, C_2, D_2 and F_2 from the second assembly of test and reference elements may be switched, if desired, or, as indicated in Figures 7 and 8, a second complete receptacle 250 is provided on the probe body portion that remains outside of the pipe or container, so that a connector 217, as shown in Figure 7, coupled to the instrument computing and readout circuits can be alternatively connected to either the second receptacle 260 or to the first receptacle 215.

In the embodiment of Figures 7 to 10, a third assembly of wire loop test element 230a and reference element 214b is mounted in the probe body 210. The test element is also exposed to the corrosive environment with the other test elements, and its reference element (having the same diameter as the first and second reference elements) is protected from the corrosive environment. A third set of five leads A_3, B_3, C_3, D_3, F_3, is connected to the third test and reference element assembly and brought out to a third receptacle 260 (Figures 7 and 8) that is connected to the instrument connector at the end of the useful life of the second test element 230. The third test element 230a has a diameter twice that of the first test element when new. All three reference elements have the same diameter. Preferably, all wires are of the same material. The reference element 214a of the second assembly of the test and reference elements may be made with the same diameter as the second test element, when new, and made from the same piece of wire for maximized temperature compensation. In such case, the length of the second reference element is greater than the length of reference element 214, being chosen so that the ratio of the resistance of the second test element 230, at the end of the life of the first test element 216, to the resistance of the second reference element is the same as the ratio of the resistances of the first test and reference elements when new.

Thus, in the arrangement of Figures 7 to 10, it is only necessary to move the instrument coupled connector 217 in sequence from receptacle 215 to receptacle 250 at the end of the useful life of test element 216 and from receptacle 250 to receptacle 260 at the end of useful life of test element 230.

It will be appreciated that other modifications of the described invention may be made. A combination of multiple test elements and multiple reference elements may be arranged so that, for example, after a first test element has reached the end of its useful life, a second initially larger test element now has the same diameter as the new diameter of the first test

element and is switched in for use with a first reference element. At the end of the useful life of the second reference element (that is, when it is corroded down to 50% of the diameter of the first test element when new), a second reference element may be employed with the second test element to provide a corrosion signal, as measured by the ratio of the resistance of the second test element to the second reference element. Such an arrangement would provide two extensions of the probe life and thus, in effect, triple the probe life.

Where multiple test elements are employed, some situations may enable the second test element to initially have the same size as the first test element, but to be formed of a material that corrodes at a decreased rate. Accordingly, with such an arrangement, when the first test element has corroded to 50% of its new diameter, the second test element will have corroded a lesser amount, such as, for example, to 70% or 80% of its initial diameter. The second test element may then be switched into use. Resistance ratio readings are provided using the same reference element. The second test element will continue to indicate corrosion, but at a decreased sensitivity caused by the lesser rate of corrosion of the second test element. In such an arrangement, the probe life is extended, but sensitivity is decreased during the extended portion of its life, whereas in arrangements previously described, probe sensitivity does not diminish as new test or reference elements are employed.

It will be seen that life of an electrical resistance probe is extended by mounting in the one probe body a set of resistive test elements and a set of resistive reference elements. In different embodiments there may be one, two or more elements in each set and either the same or different numbers of elements in the two sets. Thus, there may be two or more elements in the test element set and one or more in the other set, or vice versa. The sets are arranged so that resistance of an element in one set is compared with resistance of an element of the other set for a first period of probe operation. For a following period of probe operation, the same or a different element of the one set is compared with a different element of the other set. There may be a common reference element for successive comparison with different test elements or a common test element for successive comparison with different reference elements, or there may be no common element but successive comparisons of unique pairs of different elements of the two sets.

There have been disclosed methods and apparatus for extending useful life of an electrical resistance corrosion probe by factors of two, three or more, without loss of sensitivity, thereby minimizing time, effort, costs and other inconveniences of more frequent probe replacement. The described embodiments of the invention add little to the cost, manufacture, or operation of the extended life probes and thus provide a significant advantage to the user.

CLAIMS

1. An electrical resistance corrosion probe comprising a probe body, test means mounted on and extending away from the body and being arranged to be exposed to a corrosive environment, reference means mounted on the body and protected from the corrosive environment to which the test means are exposed, the test or reference means comprising first and second resistive elements, and the other of the test or reference means comprising a third resistive element, means for generating first, second and third resistance signals respectively indicating the resistance of the first, second and third resistive elements, and measuring means for comparing the third resistance signal with the first resistance signal during a first part of the life of the probe and for comparing the third resistance signal with the second resistance signal during a subsequent part of the life of the probe.

2. A corrosion probe as claimed in claim 1, in which the first and second resistive elements form the reference means with the resistance of the first resistive element being less than that of the second resistive element, the resistance of the first resistive element being matched to that of the test means, the third resistive element, before any corrosion of the test means has occurred, and the resistance of the second resistive element being matched to that of the test means, the third resistive element, after a predetermined degree of corrosion of the test means has occurred.

3. A corrosion probe according to claim 1, in which the first and second resistive elements form the test means, with the resistance of the first resistive element being matched to that of the third resistive element, the reference means, before any corrosion of the test means has occurred, and with the resistance of the second resistive element being matched to that of the third resistive element, the reference means, after a predetermined degree of corrosion of the test means has occurred.

4. A corrosion probe according to claim 3, in which the first and second resistive elements forming the test means are made from different materials having different corrosion rates, the second resistive element being more resistant to corrosion than the first.

5. A corrosion probe according to claim 3, in which the first and second resistive elements forming the test means are made from the same material, the cross-sectional area of the second resistive elememt being greater than that of the first resistive element to such an extent that, after the predetermined degree of corrosion has taken place the cross-sectional area of the second resistive element is substantially the same as the initial cross-sectional area of the first resistive element before corrosion.

6. An electrical resistance corrosion probe having a first test element adapted to be exposed to a corrosive environment, reference means including a reference element protected from the corrosive environment and means for comparing resistances of the elements to generate a corrosion signal, including a second test element mounted adjacent the first test element and adapted to be exposed to the corrosive environment, the second test element having a cross sectional area greater than that of the

first probe, and means for comparing resistances of the second test element and the reference means after the test elements have been corroded by the environment.

7. A corrosion probe according to claim 1, wherein a predetermined relation of the resistance of the first test element before corrosion to the resistance of the reference means is the same predetermined relation as the resistance of the second test element after corrosion to the resistance of the reference means.

8. A corrosion probe according to claim 6 or 7, including means for generating resistance signals respectively indicative of resistances of the elements, and wherein the means for comparing comprises a corrosion indicating circuit, means for feeding the resistance signal of the reference element to the circuit, and means for selectively feeding the resistance signals of either the first or second test elements to the circuit so that the reference element resistance signal is compared with one or the other of the test element resistance signals.

9. A probe according to claim 6, 7 or 8, wherein the reference means comprises first and second reference elements protected from the environment, and wherein the means for comparing comprises means for comparing resistances of the second test element and the second reference element.

10. A corrosion probe according to claim 6, 7, 8 or 9, wherein the means for comparing resistances collectively comprise first test means for generating a first test signal indicative of the resistance of the first test element, reference means for generating a reference signal indicative of the resistance of the reference element, comparison means having first and second inputs responsive to the first test and reference signals for generating the corrosion signal, second test means for generating a second test signal indicative of resistance of the second test element, and means for switching one of the comparison means inputs from the first test sigal to the second test signal.

11. A corrosion according to claim 6, including a probe body, both of the test elements being mounted on the body for exposure to a corrosive environment when the body is exposed to such an environment, the reference element being mounted within the body, means for generating resistance signals respectively indicative of the resistance of the elements, the comparison means comprising a circuit having first and second inputs, the first input being connected to receive the resistance signal of the reference element and switch means for alternatively transmitting to the second input the resistance signal of one or the other of the test elements.

12. An electrical resistance corrosion probe comprising a probe body, first and second test elements mounted on and extending from the probe body and adapted to be exposed to a corrosive environment, reference means including at least one reference element within the probe body, means for comparing the resistance of the reference element with the resistance of the first test element to generate a first corrosion signal, and means for comparing resistance of the reference means with resistance of the second test element to generate a second corrosion signal.

13. A corrosion probe according to claim 12, wherein the second test element has a cross sectional area greater than the cross section area of the first test element.

14. A corrosion probe according to claim 12, wherein the second test element has a slower rate of corrosion than the first test element.

15. A corrosion probe according to claim 13 or 14, wherein the ratio of the resistance of the second test element to the resistance of the reference element, after the test elements have been corroded to the end of a predetermined useful life of the first test element, is substantially the same as the ratio of resistance of the first test element to resistance of the reference element, before the test elements have been exposed to a corrosive environment.

16. A corrosion probe according to any one of claims 12 to 15, wherein the means for comparing comprises means for indicating the ratio of the resistance of the second test element to the resistance of the reference element.

17. A corrosion probe according to any one of claims 12 to 16, wherein the reference means includes a second reference element, and wherein the means for comparing comprises means for indicating the ratio of the resistance of the second test element to the resistance of the second reference element.

18. A corrosion probe according to any one of claims 12 to 17, wherein both the said means for comparing resistance collectively comprise a comparison circuit having first and second inputs, the first input being coupled to receive a signal indicative of the resistance of the reference element, and the second input being connected to receive either a first test signal indicative of the resistance of the first test element or a second test signal indicative of the resistance of the second test element, whereby the comparison circuit receives a signal indicative of the first test element resistance for comparison with the reference element resistance for a first period of time during which the test elements are exposed to the corrosive environment, and then receives the signal from the reference element and a signal indicative of the resistance of the second test element during a following period of time.

19. A corrosion probe according to any one of claims 12 to 17, wherein the means for comparing comprises means for initially comparing the resistance of the reference element with the resistance of the first test element and, after both the test elements have been exposed to the corrosive environment for a period of time, comparing the resistance of the reference test element with the resistance of the second test element.

20. A corrosion probe according to any one of claims 12 to 19, wherein the ratio of the resistance of the first test element to the resistance of the reference element has a predetermined value prior to exposure of the test elements to a corrosive environment, and wherein the means for comparing the resistance of the reference element with the resistance of the second test element to generate a

second corrosion signal comprises means for initiating generation of the second corrosion signal when the ratio of resistance of the second test element to the resistance of the reference element substantially attains the predetermined value.

21. A corrosion probe according to any one of claims 12 to 20, wherein both the test elements are exposed to the same corrosive environment for a period of time substantially equal to the useful life of the first test element, and wherein generation of the second corrosion signal is initiated at the end of the period of time.

22. An electrical resistance corrosion probe for detecting corrosion by comparison of the resistance of test and reference elements, comprising a probe body, a set of resistive test elements mounted on and extending from the probe body and adapted to be exposed to a corrosive environment, a set of resistive reference elements mounted on the probe body and protected from the corrosive environment, means for comparing the resistance of one element of the test element set with the resistance of one element of the reference element set during a second period subsequent to the first period to generate a second corrosion signal, at least one of the elements the resistance of which is compared during the second period being different from the elements the resistance of which is compared during the first period.

23. A corrosion probe according to claim 22, wherein one of the sets includes first and second elements and wherein the other of the sets includes a common element, the resistance of the common element being successively compared with resistances of the first and second elements in respective periods.

24. A corrosion probe according to claim 22 or 23, wherein the set of test elements comprises first test element, a second test element having a larger cross sectional area than the first test element, wherein the set of reference elements comprises a single reference element, and wherein the means for comparing resistance comprises means for comparing resistances of the first test element and the reference element during the first period and for comparing resistances of the second test element and the reference element during the second period.

25. A corrosion probe according to claim 22 or 23, wherein the set of test elements comprises a single test element, wherein the set of reference elements comprises a first reference element and a second reference element having a resistance greater than the resistance of the first reference element, and wherein the means for comparing resistances comprises means for comparing resistance of the test element with the resistance of the first reference element during the first period and means for comparing the resistance of the test element with the resistance of the second reference element during the subsequent period.

26. A corrosion probe according to claim 22 or 23, wherein the set of test elements comprises first and second test elements, the second test element having a larger cross sectional area than the first test element, wherein the set of reference elements comprises first and second reference elements, and wherein the means for comparing resistance comprises means for comparing the resistances of the first test element and the first reference element during the first period and means for comparing the resistances of the second test element and the second reference element during the second period.

27. A corrosion probe according to claim 22 or 23, wherein the set of test elements comprise first and second test elements, the second test element having a different corrosion rate from the first test element, wherein the set of reference elements comprises a single reference element, and wherein the means for comparing resistance comprises means for comparing the resistances of the first test element and the reference element during the first period and for comparing the resistances of the second test element and the reference element during the second period.

28. A method of extending the life of a corrosion probe of the type having a probe body arranged to be placed in a corrosive environment with a corrosion test element that is exposed to the corrosive environment and a reference element protected from the environment, and in which the electrical resistances of the test and reference elements are compared to indicate corrosion, the method comprising forming a second test element having an electrical resistance before corrosion that is significantly less than the electrical resistance of the first test element before corrosion, mounting the second test element on the probe body for exposure to the corrosive environment together with the first test element, and comparing the electrical resistance of the reference element with the electrical resistance of the second test element after both test elements have been exposed to the corrosive environment.

29. A method according to claim 28, wherein the test elements exposed to the corrosive environment have a finite useful life, and wherein the method includes the steps of using the comparison of the resistance of the first test element and the resistance of the reference element to indicate corrosion during the finite life of the first test element and using comparison of the resistance of the second test element and the resistance of the reference element to indicate corrosion after the first test element has been corroded to a point near the end of its finite life, the second test element having a longer useful life than the first test element.

30. A method according to claim 28 or 29, wherein the electrical resistance of the second test element is compared to the electrical resistance of the reference element is initiated to indicate corrosive tendencies of the environment when the ratio of the resistance of the second test element to the resistance of the reference element is substantially equal to the ratio of the resistance of the first test element, before corrosion, to the resistance of the reference element.

31. A corrosion probe substantially as described with reference to the accompanying drawings.

32. A method of monitoring the corrosive properties of an environment substantially as described with reference to the accompanying drawings.

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